International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN (P): 2249-6890; ISSN (E): 2249-8001
Vol. 8, Issue 3, Jun 2018, 227-234

A COMPARATIVE STUDY ON DYNAMOMETER PERFORMANCE EVALUATION OF FLY ASH CONTAINING ORGANIC AND SEMI-METALLIC MOTORCYCLE DISC BRAKE PADS

VENKATA NAGA BAJI TOKALA[1], CHITHARANJAN KANNEGANTI[2] & NARENDRA KESANA[3]

[1]Associate Professor, Department of Basic Science and Humanities, Vignan's Lara Institute of Technology & Science, Andhra Pradesh, India

[2]Lecturer, Department of Physics, P. B. N. College, Nidubrolu, Andhra Pradesh, India

[3]Assistant Professor, Department of Basic Science and Humanities, Malla Reddy college of Engineering and Technology, Telangana, Andrapradesh, India

ABSTRACT

Semi-metallic and fly ash containing organic formulation based friction composites have been fabricated and evaluated for drag braking performance on a Dynamometer friction testing machine conforming to ST-1037 Schedule. ST-1037 dynamometer test schedule is followed by a leading brake system supplier. Composites have been characterized for their physical, thermal, mechanical and tribological performance. Semi-metallic based composites (SMBC) have shown better thermal resistance than fly ash containing organic formulation based composites (FAOC). Mechanical properties such as hardness, shear strength, and compressibility have been found to be similar for both the composites. FAOC composites have shown better wear resistance while acquiring comparable coefficient of friction values. The load-speed sensitivity of the composites has been further investigated to simulate the on-road conditions. Topographical variations and their possible roles in controlling the tribological performance have been characterized by worn surface morphology. Counter-face friendliness of the brake pads have been investigated by scouring test and found to be better for non-ferrous organic formulation based composites

KEYWORDS: Semi-Metallic Based Composites (SMBC), Fly Ash Based Composites (FAOC), Wear Resistance & Tribological Performance

Received: Mar 19, 2018; **Accepted:** Apr 09, 2018; **Published:** Apr 30, 2018; **Paper Id.:** IJMPERDJUN201826

INTRODUCTION

Semi-metallic based composite is widely being used as a friction material for motorcycle brake pads. Despite their good tribological performance, such composites are found to be more sensitive to braking load-sliding speed fluctuations and hence offer low wear resistance. Disc blackening and scoring are of major concerns for semi-metallic based composites, which limits its potential application. On the other hand, fly ash containing organic pads offer improved wear performance, more friction stabilization, better water spray friction performance, (an aspect very critical while using friction pads in waterlogged areas), more counter-face friendliness and reduced squeal and vibration. Furthermore, organic pads reduce scouring and disc blackening. An attempt is made to fabricate such organic based composites followed by their comparative assessment against conventional semi-

Original Article

metallic based composites in terms of their thermal, mechanical and tribological performance point of views.

EXPERIMENTAL

Fabrication and Characterization of Composites

Hybrid friction composites based on non-ferrous organic and semi-metallic composition were manufactured and evaluated for their physical, thermal, mechanical and tribological performance. The compositional variations and the nomenclature of the composites are given in Table 1. To ensure mechanical isotropy the ingredients were mixed in a plow shear mixer.

Table 1: Composite Formulation and Designation

	Fly Ash Containing Organic Formulation (FAOC) wt.%	Semi - Metallic Formulation (SMBC) wt.%
Binder	14.66 (Phenolic resin)	5.23 (Phenolic resin)
Filler	27.92(Barytes/Calcined petroleum coke/Fly ash/calcium oxide)	16.86 (Barytes/Calcined petroleum coke)
Fibre	2.49 (Kevlar)	38.94 (Kevlar/Paper pulp/Steel /Potassium titanate)
Friction modifier	11.25 (Antimony trisulphide/ Graphite flakes)	22.93(Antimony trisulphide/ Graphite flakes/Friction dust)
Special additives	43.68 (Nitrile rubber powder/Copper powder fine/Alumina/Magnesium oxide)	16.04 (Tyre peels/SBR powder/Alumina/Grinding dust)

The molding conditions were adopted as per standard industrial practices depending on the curing isotherm of novolac resin**.** The ingredients along with the resin were performed and then compression molded at 155ºC, under a pressure of 2.3 ton/inch^2 for 5 minutes with intermittent breathings to expel the volatiles out. The FAOC composite pads were then post-cured in an oven at 150ºC for 4hrs while the SMBC pads were cured at 180ºC for 6 hours for preventing cracking due to build of residual internal stresses during earlier processing step. The friction surface was then ground to wipe off the resinous skin layer. The composite brake pads were further characterized for their various properties.

Physical and Mechanical Characterization

The composites were characterized by their physical and mechanical properties such as density, hardness, shear strength and compressibility**.** Density was determined using Archimedes' principle of measurement of the weight of the specimen in air and in water, respectively. The mechanical property such as hardness (defined as the resistance to local deformation) was measured by Rockwell hardness tester from Fuel Instruments & Engineers Pvt. Ltd as per BSAU 142/68 to confirm uniform mixing and proper curing during the fabrication. Shear strength (a measure of composite integrity and its adhesion with the back plate) was measured on the Universal testing machine from Fuel Instruments & Engineers Pvt. Ltd. and compressibility (A measure of the change in thickness under elastic or standard load) were measured on compressibility testing machine from Hind Hydraulic Ltd, India.

Thermal Characterization

Differential Scanning Calorimetry (DSC) was carried out on a Q 200 machine from TA Instruments; the USA to measure the curing characteristic of the phenolic resin. Thermal gravimetric analysis (TGA) of the prepared brake pads was carried out on the machine from Shimadzu to study the degradation behavior.

Tribological Performance Evaluation Methodology

Tribological evaluation of the friction composites has been investigated on brake inertia Dynamometer for evaluation of pad performance conforming to ST-1037 Schedule (Inertia 18.55 kg-m^2, Disc Dia-240mm, Speed corresponds to 20-90 km/hr in performance test and 60 km/hr in wear test, Pressure 20- 65 bars in performance test while 35 bars on wear test, wear cycles each consisting of 60 braking applications).

Worn Surface Analysis

Worn surface morphology of the friction composites has been investigated by scanning electron microscopy **(SEM)** on a Zeiss EVO-MA15 microscope. The specimen surfaces were gold sputter coated in a sputtering unit prior to microscopic examination. The accelerating voltage was 20 kV. Furthermore, Energy dispersive X-ray analysis **(EDX)** was performed to quantitatively investigate the elemental composition of the developed third body friction layer.

Scouring / Scratch Mark Testing Methodology

Comparative tests were carried out on new discs and photographs were taken after 5 braking applications in each case. The speed of the motorcycle was maintained at 40 km/hr (as per OEM customer requirement) and normal brakes were applied till full stop.

RESULTS AND DISCUSSIONS

Physical and Mechanical Properties Investigations

The experimental results of physical and mechanical properties of the composites are presented in Table 2. The densities of the composites (FAOC& SMBC) were found to be very similar. On the other hand, mechanical properties viz. Hardness, shear strength and compressibility of the semi-metallic based composites (SMBC) were found to be slightly better than that of non-ferrous organic formulations based composites. Both the composites showed their mechanical and physical properties well in the acceptable range as per the industrial practice

Table 2: Physical and Mechanical Properties of Friction Pads

Properties	Fly Ash Containing Organic Formulation (FAOC)	Semi – Metallic Formulation (SMBC)
Density	2.73	2.77
Hardness (R-scale)	96 (85-105)	98 (92-106)
Shear strength KgF	898 (790-1100)	910 (790-1080)
Compressibility microns	68 (64 – 76)	63(58 – 69)

Thermal Characterization

DSC curve indicates that the curing of the resin starts at 151°C and reaches a maximum at 159°C and ends at 171°C as shown in **Figure 1**.

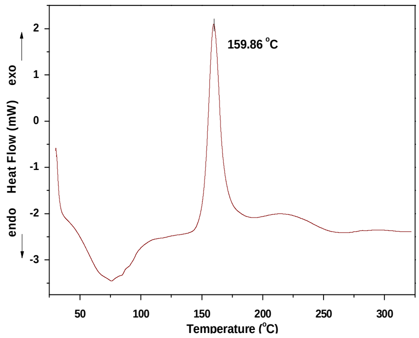


Figure 1: Curing Isotherm of Phenolic Resin

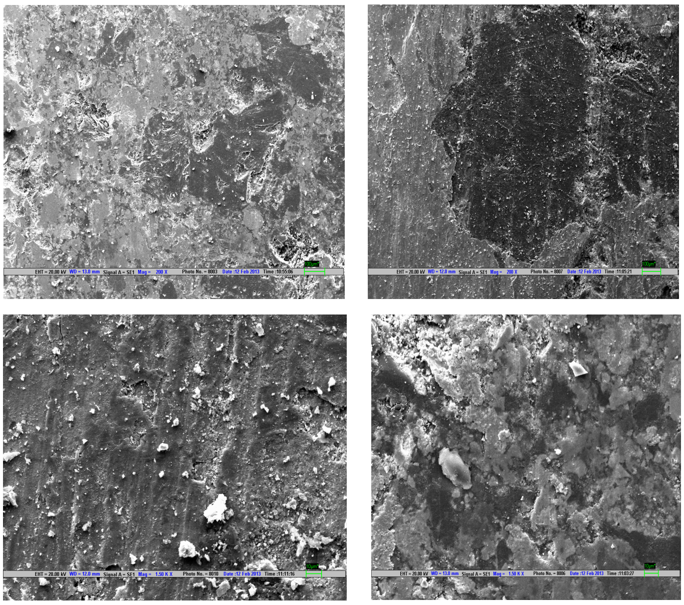


Figure 2: TGA Scans of Friction Pads

Thermo-gravimetric analysis (TGA) of the prepared pads has shown similar degradation behavior for both semi-metallic and fly ash containing organic formulation based composites till 600^{o}C as evident from **Figure 2**. A further increase in the temperature led to faster degradation for organic formulation based composites. On the other hand, semi-metallic based composites showed a slight increase in the weight, which is further attributed to oxidation of the metallic constituents in the pads.

Friction Performance of the Composites

Figure 3 depicts the friction response of the brake composites at a specified load of 20, 35, 50 and 65 kg/cm^2. The speed of the counter-face was varied in the range of 20-90 km/hr at each specified load.

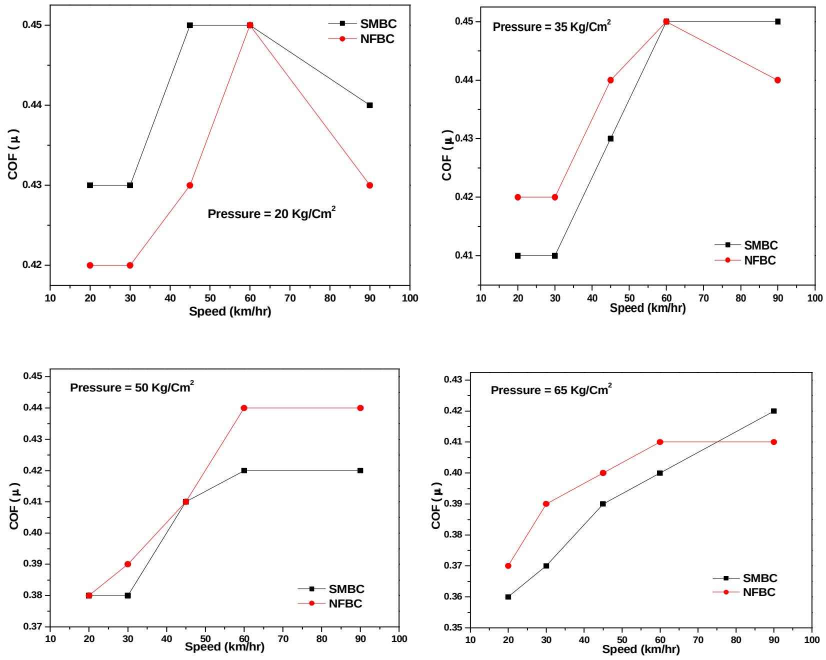


Figure 3 Load-Speed Sensitivity of Semi-Metallic (SMBC) and Fly Ash Containing Organic (FAOC) Based Friction Composites

The coefficient of friction value for both the composites was found to be in the range of 0.35-0.45. At lower load, semi-metallic based composites have shown higher COF values. On the other hand, at higher load non-ferrous organic formulation based composites have shown higher COF values. The overall performance of the friction values, the fade and recovery response of the brake composites are shown in **Table 3.**

Table 3: Physical and Mechanical Properties of Friction Pads

Acceptance Criteria	Non-Ferrous Organic Formulation (FAOC)	Semi – Metallic Formulation(SMBC)
1. Mean value of friction : 0.35~0.45	0.42	0.41
2. Min. friction value after fade: 0.30	0.39	0.35
3. Min. friction value for last braking during water spray test : 0.30	0.36	0.33
4. Recovery after fade & water spray test must be within 10 cycles	OK	OK
5. The friction sensitivity for speed & pressure must be within 20% for speed range of 20-90 km/hr at specific pressure range of 20-65 bar	OK	OK

Wear Behavior of the Composites

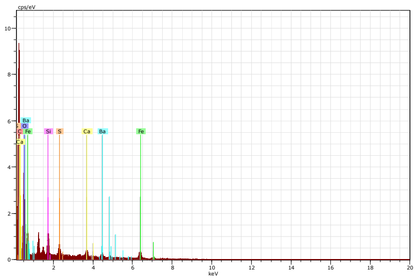
Volumetric wear is calculated by measuring the wear weight (weight loss due to wear) followed by normalization with the density of the standard specimen after the completion of the Tribology test on the dynamometer testing machine. Volumetric wear of friction pads at different cycles is shown in **Table 4.** Non-ferrous organic formulations **(FAOC)** based composites have shown higher wear resistance than that of semi-metallic based composites.

Table 4: Wear Performance of Friction Pads at Different Cycles

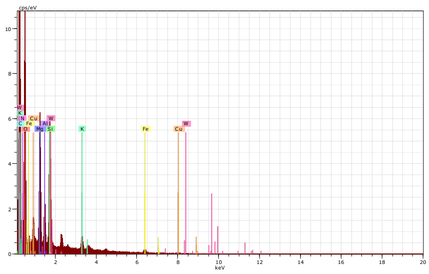
Pads	After 20 Cycles		After 40 Cycles	
	Wear (gm)	Wear (mm)	Wear (gm)	Wear (mm)
Non-Ferrous Organic Formulation (FAOC)	1.00	0.24	1.70	0.41
Semi – Metallic Formulation (SMBC)	1.20	0.29	2.03	0.49

Worn Surface Analysis

Worn surface morphology of FAOC and SMBC composites is done to study the failure mechanism. Micrographs at lower magnification (**Figure 4a-b**) have indicated very smooth secondary patches for an organic formulation based friction composites whereas semi-metallic based friction composites showed layered patches, which is indicative of repetitive crushing of wear debris. Furthermore, energy dispersive X-ray analysis of the composites has shown higher Fe-content for semi-metallic based friction composites. Organic formulation based composites also showed Fe-content, which may be attributed to the fact that third body film contains materials from both the pad as well as the disc.



(a)
Figure 4(a): SEM scans at Lower and Higher Magnifications of SMBC and their EDX Spectra



(b)
Figure 4(b): SEM Scan at Lower and Higher Magnification of FAOC and their EDX Spectra

Scouring / Scratch Mark Test

The counter-face friendliness of the brake pads, which is an important characteristic of such friction composite, has been investigated via scouring test. Comparative tests were carried out on new discs and photographs were taken after 5 brake applications in each case **(FAOC& SMBC).** The speed of the motorcycle was maintained at 40 km/hr and normal brakes were applied till full stop. The photographs of the counter-face against both the friction composite after the 50brake application has been shown in **Figure 5a-b**. The disc blackening in FAOC friction composite has been found to be better (less blackening and less scratch mark) than SMBC grade.

(a)
Figure 5(a): Counter-Face Against FAOC Friction Pad after 50 Brake Application

(b)
Figure 5(b): Counter-Face Against SMBC Friction Pad after 50 Brake Application

CONCLUSIONS

Tribological performance of semi-metallic and non-ferrous organic formulation based friction composites have been evaluated in drag-braking mode on a Dynamometer friction testing machine following ST-1037 standard. The mechanical properties such as hardness, compressibility, and shear strength remained within the acceptable limits for both the composites. Physical and mechanical properties are comparable to semi-metallic pads indicating a minimum compromise in the qualitative attributes of performance. Fly ash containing Organic pads is found to be less sensitive to braking load-sliding speed fluctuations than the semi-metallic pads. More of organic content in formulations facilitate smoothen the friction performance. Wear resistance is enhanced by ~ 20% in organic pads. Wet performance tests show organic pads having an edge over semi-metallic motorbike pads. The operational durability of organic pads is seen to be longer because the temperature attained during motorcycle riding is approx 130°C - 170°C. Semi-metallic composites usually perform better at a higher temp. Less disc-blackening and disc scouring in organic pads in comparison to semi-metallic based composites further showed enhanced counter-face friendliness of such composites. This is necessary due to the fact that some motorcycle buyers at the showrooms were not comfortable with disc blackening and scouring prior to use. This detailed study confirms that the organic composition is more suitable for motorcycle brake applications.

REFERENCES

1. *J Bijwe, Polym. Compos. 18(3) (1997) 378-396.*
2. *S. K Rhee, Wear 28 (1974) 277-281.*
3. *Gopal P, Dharani L R, and Blum F D, Wear, 174 (1994) 119-127.*
4. *Lee K J, Lin J H C, and Ju C P, Wear, 199 (1996) 228-236.*
5. *Jullien A, Meurisse M H, and Berthier Y, Wear, 194(1996) 116-125.*
6. *Herring J M, SAE Trans, Paper No. 670146, (1967).*
7. *Anderson A E, Friction, Lubrication and Wear Technology, ASM Hand Book, ASM Materials. Information Society, USA, 18 (1990) 569-577.*
8. *Wirth A, Eggleston D, and Whitaker R, Wear, 179(1994) 75-81.*
9. *Bark L S, moran D, and Percival S J, Wear 53 (1979) 107-113.*